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# Accumulation and Translocation of Heavy Metals in *Coriandrum sativum*

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## ABSTRACT

*Contamination of toxic trace metals represents one of the most pressing threats to water and soil resources as well as human health. Phytoremediation can be potentially used to remediate metal-contaminated sites. In this study the potential of medicinal plant Coriandrum sativum was examined to determine if this plant show sufficient tolerance and accumulation to be used for phytoremediation of the polluted soil. Plant and the associated soil sample were collected and analyzed for total metal concentrations. The distribution of toxic metals such as Mn, Fe Cu, Ni, and Zn in roots, and leaves of the plant was determined by acid digestion and inductively coupled plasma mass spectrometry. From the result obtained it is evident that the roots absorb high concentrations of metals Mn. Fe, Cu, and Zn from the soil. The mean concentration of Mn, Fe, Ni, Cu and Zn in the rhizospheric soil are found to 44652, 4922, 63027, 83, 94, and 104 mg kg*$^{-1}$*. The order of decreasing concentration of all the metals found in the rhizospheric soil is: Fe>Al>Mn>Zn>Cu>Ni. The concentration of metals such as Al, Mn, Ni, and Cu are always present in a higher amount in the plant leaf than root. The biological absorption coefficient (BAC) and translocation factor (TF) for the phytoremediation are also discussed.*

**Keywords:** *Coriandrum sativum*, Toxic metal uptake, Phytoremediation, Bioaccumulation factor, Translocation factor.

## INTRODUCTION

The controls of the heavy metals content in medicinal and aromatic plant represent one of the factors for the evaluation of their quality. The high heavy metal content in some medicinal plants arises from their ability to accumulate particular metals. However, high heavy metal uptake because of certain properties of these soils, such as acidity and /or the presence of metal-bearing minerals, which favors the mobility of heavy metals in a soil and their high availability to plants [1-3]. Plant requires at least 17 elements to complete their life cycles, including the heavy metals Cu, Zn and Ni. Plants also accumulate nonessential metals, such as Pb and Cd, when each is present in the environment [4]. Metals contained within plant tissues are acquired from the soil solution, and plants have evolved elaborate rooting systems and transport mechanisms to mediate this process. Plant remains of great importance to evaluate their potential for the phytoremediation of metal-polluted soil. Plants display a wide range of adaptations to soils with contrasting metal contents. Such adaptations have occurred throughout evolution. Some of the heavy metals are believed to be essential including iron, zinc and copper. Some metal ions as cadmium, lead and mercury have toxic roles in biochemical reactions in our body. It is a strong link between micro-nutrient, nutrition of plants, animals, and humans [5-7]. Heavy metal uptake, translocation, and sequestration are key aspects of a plant's ability to accumulate and cope with high concentrations of heavy metals. Heavy metals such as Cr, Mn, Fe, Co, Ni, Cu, Zn, As, and Pb are an increasing environmental problem worldwide. Plants can be used to remove heavy metals by accumulating, stabilizing, or biochemically transforming them. This cost-effective and environmentally-friendly technology has been called "phytoremediation" [9-11]. Hyper accumulator plants show a stronger influx of heavy metals into the roots than do non-accumulator species [12]. Hyper-accumulators plants offer one option for the phytoremediation of metal-contaminated sites. Non-hyper-accumulator plants tend to store the absorbed heavy metals in the roots, whereas hyper-accumulator plants are capable of transporting most of the accumulated heavy metals to the shoots. Since plants originate from different growing areas, great differences in the uptake and concentrations of heavy metals in the plant tissue may be expected [13]. The high heavy metal content in some medicinal plants arises from their ability to accumulate particular metals [7]. Although essential micro-nutrients such as Zn, Ni, Cu, and Mn play an important role in different aspects of a plant's metabolism, each is also potentially toxic heavy metals. Likewise, other non-essential toxic heavy metals, such as Cd and Pb, with similar physicochemical properties, but lacking a biological function enter the plant via the transport systems operating for micro-nutrient acquisition. The level of heavy metal concentration in *Coriandrum sativum* is a matter of health, as well as an important component defining processing technology [8, 14, 15].

The objectives of this study was (1) to study the plant species composition and diversity in the adversely contaminated environment, (2) to identify the ability of plant successfully grow and reproduce in contaminated soils, and (3) to assess metal accumulation capacities for use in phytoremediation practice [16, 17]. In the present investigation *Coriandrum sativum* was selected for the heavy metal accumulation. The available and total metal contents in rhizospheric soil as well as metal contents in dried matter were also described.

## MATERIALS AND METHODS

**Sampling of soil and plant material:** The different parts of *Coriandrum sativum* (i.e. leaf, stem, root etc.) and rhizospheric soil was collected from contaminated sites of Chhattisgarh, central India. The plants were washed thoroughly with deionized distilled water, dried in a shed, and compressed into a powder with the help of a manual grinder and sieved out the particles of mesh size, < 0.1mm.

**Chemicals and Reagents:** The AR grade (E. Merck) chemicals were used for digestion of the soil and plant samples. The ICP multi-element (23 elements) standard (E. Merck) was used for preparation of the calibration curve.

**Soil and plant sample preparation and analysis:** The Plant and Soil sample air-dried, weighed and placed in a dehydrator at approximately 80°C for 48-72 h depending on sample size. The samples were ground to a fine powder with mortar and passed through a sieve of < 0.1 mm mesh size. The weighed amount (0.5 g) of the sample was digested with 5 ml $HNO_3$+2 ml $HClO_4$+1 ml HF in the closed microwave oven as prescribed in the literature. An instrument inductively coupled plasma-atomic emission spectrometry (ICP-AES) Ultima-2 from Jobin Yvon, France equipped with parallel flow nebulizer and the cyclonic spray chamber was used for the monitoring of the heavy metals (i.e. Cr, Mn, Fe, Cu, Zn, Pb). The flow rate of argon plasma, sheath and nebulizer gas maintained was 12, 0.2 and 0.8 l $min^{-1}$, respectively at sample uptake of 1 ml $min^{-1}$. The operating parameters for working elements were set as recommended by the manufacturer.

Soil pH was measured in a 1: 5 (w $w^{-1}$) soil to distilled water mixture. The leaves of the plants collected in the field were rinsed in distilled water and dried overnight at 70°C. Plant (root, stem, leaf, etc.) samples were washed as described earlier.

## RESULTS AND DISCUSSION

**Characteristics of soil containing alkali and alkaline earth metals:** The reaction of the soil was determined by measuring the pH of a 1:2.5 soil/water suspension using a pH meter fitted with a glass electrode. Equilibrium between the electrodes and the soil suspension is not attained very rapidly, and sufficient time must be allowed for the attainment of equilibrium before taking the reading [**17**]. In soil the alkali and alkaline earth metal e.g. Na, K, Ca, Mg, etc. concentrations are also determined. The quantity of Na, Mg, K, and Ca are measured because they constitute almost all of the basic nature found in soils. Thus, the summation of these metals estimates the alkaline nature of the soil. PH of the soils collected from different locations is in the range from 7.13-7.65 with the mean value of 7.34 (Table 1).

**Table 1.** Soil and Plant Morphology

| S.No. | Spot | Site characteristics | PH of the soil | Age of plant (in days ) | Water Percentage |
|---|---|---|---|---|---|
| 1 | S-I | Sewage blackish soil | weak alkaline | 40-45 | 84 |
| 2 | S-II | Sewage blackish soil | weak alkaline | 35-40 | 86 |
| 3 | S-III | Red soil | weak alkaline | 35-40 | 87 |
| 4 | S-IV | Red soil | weak alkaline | 30-40 | 87 |
| 5 | S-V | Brownish soil | weak alkaline | 20-30 | 91 |
| 6 | S-VI | Blackish soil | weak alkaline | 45–50 | 74 |
| | | Mean ± SD | 7.36 ± 0.18 | | |

In this study the uptake of Al, Mn, Fe, Ni, Cu, and Zn from soil to root biological absorption coefficient (BAC) and root to leaf translocation factor (TF) were compared in *Coriandrum sativum* from different soil types (Table 2). Bioaccumulation factor (BAC) and Translocation factor (TF) has been used as an index to measure the effectiveness of plant metal translocation from soil to root and from roots to leaf (Ernst, 2002, Pilon-Smits *et al*., 2002). The BAC from soil to component parts of plant, expressed as the ratio of metal concentration in part divided by the concentration of metal in soil, may be an indicator of the palnt accumulation behavior. In this study it is estimated and compared the values of the bioaccumulation factor (BF) of Cd, Zn, Ni, Cu, Pb, Fe and Mn from soil to different part of plant.

Bioaccumulation factor is calculated with relation:

$$BAC = Cp/Cs \qquad ...(i)$$

where: Cp is the mean metal concentration in plant sample (mg $kg^{-1}$) and Cs is the mean metal concentration in soil sample (mg $kg^{-1}$).

If the BF > 1 then the plants can be accumulators, BF = 1 is no influences and if the BF < 1 then the plant can be an excluder [**15, 18**].

The root is adapted to carry out the main functions: one for fixing plant in soil and one for absorption water and dissolved minerals. The root contributes to the metabolism of plant feeding the whole plant and often serves to store minerals. This ability of roots to accumulate heavy metals is considered to be a way that the aerial parts of the plant are protected. Adsorption of heavy metals and their transport to the plant part depend mainly on the type of metal, in the second on the biological role in plant, and the metal ability to form some complexes with the sap components. On the second place is found the outer leaf, being the old leaf, when the accumulation period of heavy metals is much longer than the other leaves. Obviously, the outer leaf is the first which is in contact with fertilizers and pesticides, as well as with acid rain or pollutants from air. Third place in this "ranking" is occupied by the core [15]. It is composed from the youngest leaves of the plant. Minerals are found in highest quantity in young leaves in growing, observing some migration of these from mature to the young leaves. The total BAC for each *Coriandrum Sativum* collected from S-I –S-V sites were presented in table 2. The BF for Al, Mn, Cu and Zn values less than 1.0 in parts of plant, but they amount exceeds this value. This fact depend both by the pH of soil (weakly alkaline or neutral). Obviously, only with BAC is no possible to establish if the plant may be considerate as accumulator species for a certain metals and these can be poisonous for people life [19-21]. However these data can be used with other data resulted by calculus of translocation factor (TF) using the next formula:

$$TF = Cplant\ part / Croot$$

Where, Cplant part is mean metal concentration in outer leaf or other parts of plant (mg $kg^{-1}$), Croot is mean metal concentration in root (mg $kg^{-1}$). Translocation factor were also presented in table 2.

**Table 2.** Bioaccumulation Factor (BAF) and Translocation Factor (TF) of metals in *Coriandrum sativum*

| Metal | Site-I | | Site-II | | Site-III | | Site-IV | | Site-V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BAC | TF | BAC | TF | BAC | TF | BAC | TF | BAC | TF |
| Mn | 0.41 | 1.52 | 0.28 | 1.53 | 0.38 | 1.49 | 0.39 | 1.49 | 0.36 | 1.38 |
| Fe | 0.03 | 1.34 | 0.02 | 1.29 | 0.05 | 1.13 | 0.21 | 1.11 | 0.20 | 0.93 |
| Ni | 0.48 | 0.37 | 0.03 | 0.2 | 0.16 | 0.24 | 0.42 | 0.18 | 0.33 | 0.24 |
| Cu | 0.71 | 0.78 | 0.65 | 0.80 | 0.35 | 1.1 | 0.84 | 0.57 | 0.77 | 0.67 |
| Zn | **0.89** | 0.86 | **0.59** | 1.23 | **0.65** | 1.26 | **0.57** | 1.31 | **0.60** | 1.27 |

*Bioaccumulation factors mean the ratio of metal concentration in above ground fronds to that in soils.
**Translocation factors mean the ratio of metal concentration in above ground fronds to that in below ground rhizoids.

The Fe and Mn is metals which are uniform distributed in all parts of plant because the value of TF is more than 1. BAC and TF for the metals Al in *Coriandrum sativum* is not significant, and both of them are very low in mean and also in range. BAC value for Mn ranges 0.28-0.41 with the mean value of 0.36 and TF value ranges 1.38 -1.53 with the mean TF value is 1.48. The both factors indicate that uptake of Mn concentration of soil is significant and a large amount of the metals is transferred towards the leaf of the plant. The translocation factor for *Coriandrum sativum* collected from different site shows a high degree of positive relation, it means that *Coriandrum sativum* can be a hyper-accumulator of Mn from soils. Plant samples collected from different types of soil and contents of moisture present in the plant does not affect the uptake of Mn from soil to root and its transportation from root to leaf. In the case of metals Fe, mean BAC value is 0.1 and TF value ranges 0.96- 1.34 with the mean value of 1.2. It means that *Coriandrum sativum* uptake Fe from soil to root and from root almost all the quantities of Fe is transferred to the leaf. There is a good positive relation of the TF value of Fe from plant samples collected from different types of soils. BAC and TF value of Ni is not so significant; it shows variation in uptake of soil to root and from root to leaf. But there is a high degree of correlation between BAC and TF value for the metal Cu and Zn. The BAC and TF for Cu ranges 035-0.84 and 0.57-0.80 with the mean value of 0.66 and 0.78. For Zn BAC and TF range 0.59-0.89 and 0.86-1.31 with the mean value of 0.66 and 1.2. In all the samples collected from different types of soils (Table 1). *Coriandrum sativum* shows highest uptake of metals Mn for site II, which is sewage blackish soil, basic in nature and the leaf contents maximum percentage of water. This result shows that *Coriandrum sativum* plant is a good hyper baccumulator of Mn, Fe, Cu and Zn. The order of transfer of these metals from root to leaf of the *Coriandrum sativum* plant collected from different types of soil follows: Mn > Fe > Zn > Cu. A lower level of investigating metals founded in the roots of the *Coriandrum sativum* plant them in the leaf of the samples, because of the transportation of the metals from the roots to the leaves [16, 15, 22-26].

## APPLICATION

Medicinal plants used for preparation of herbal products and standardized extracts for welfare of the human beings.

## CONCLUSION

*Coriandrum sativum* is interesting from both marketing and dietary points of view because cabbage has many beneficial effects on health. Taking all this information together it is concluded that the concentrations of the elements in the plant tissues were affected by their concentrations in the soil. From the result obtained it is evident that the roots absorb high concentrations of metals Mn. Fe, Cu and Zn from the soil. Of the four heavy metals applied to the soil, Zn is absorbed by the roots of plants in the highest concentration, followed by Cu, and Mn. *Coriandrum sativum* showed an affinity for Ni with moderate to high levels detected in the root and in leaves, respectively. Based on that accumulated data obtained in this study, this plant can be more effective in phytoremediation of metals from the fields. The results suggest that medicinal plants used for human consumption or for preparation of herbal products and standardized extracts should be collected from an unpolluted natural habitat.

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